Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application.

Listing of Claims:

Claim 1 (currently amended): A method of ultrasonically inspecting a disk-shaped article having a central opening and a plurality of secondary openings radially spaced outward from the central opening and circumferentially spaced from each other, the method comprising the steps of:

placing at least one ultrasonic transducer in at least a first of the secondary openings of the article;

performing a pulse-echo diagnostic technique on the article by causing the transducer to emit ultrasonic signals that intersect radials of the article at angles of approximately ninety degrees to the radials, the ultrasonic signals intersecting the radials at points so that a plurality of the points are located on a plurality of the radials; ~~and~~

receiving with the transducer a reflected ultrasonic signal that is returned from at least one of the plurality of points; ~~points.~~

calibrating the amplitude of the reflected ultrasonic signal to a flat

bottom hole standard reflector by causing the transducer to emit a calibration ultrasonic signal toward the central opening and receiving a reflected calibration ultrasonic signal from the central opening, and

calculating a relationship between the amplitude of the reflected ultrasonic signal returned from the one point to the flat bottom hole standard reflector according to the equation:

$$A_f = \lambda\, d^2\, P_f\, (b / R)^{1/2} / (2\,(R - b)\, P_r)$$

where A_f is the area of the flat bottom hole standard reflector, λ is the wavelength of sound in the article, d is the distance between the transducer and the at least one of the points, P_f is the amplitude of the reflected ultrasonic signal from the at least one of the points, b is the radius of the central opening, R is the distance between a center of the first secondary opening and a center of the central opening along one of the radials of the article, and P_r is the amplitude of the reflected calibration ultrasonic signal from the central opening.

Claim 2 (original): The method according to claim 1, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers placed in the first secondary opening, the ultrasonic transducers being pulsed simultaneously during the performing step.

Claim 3 (original): The method according to claim 1, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers placed in the first secondary opening, at least some of the ultrasonic transducers being pulsed at different times during the performing step.

Claim 4 (original): The method according to claim 1, wherein the at least one ultrasonic transducer is one of a phased array of ultrasonic transducers placed in the first secondary opening, the phased array of ultrasonic transducers being operated to focus the ultrasonic signals at predetermined depths from the first secondary opening.

Claim 5 (original): The method according to claim 1, wherein the central opening is a through-hole having an axis of symmetry and each of the secondary openings is a through-hole having an axis of symmetry that is substantially parallel to the axis of the central opening.

Claim 6 (currently amended): The method according to claim 1, wherein all of the plurality of points are located between the central opening and a circle concentric with ~~having~~ the central opening ~~as its center~~ and on which the first secondary opening is located.

Claim 7 (original): The method according to claim 1, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers mounted on a body to form a transducer unit, the placing step comprising placing the transducer unit in the first secondary opening, the body having a semicircular cross-section with a radius of curvature approximately equal to a radius of curvature of the first secondary opening.

Claim 8 (original): The method according to claim 7, wherein the article and the body on which the transducer unit is mounted are formed of the same material.

Claim 9 (original): The method according to claim 1, wherein the first secondary opening has a center located a constant distance R from a center of the central opening along one of the radials of the article, and each of the points is located a distance d from the center of the secondary opening and a distance r from the center of the central opening, the distances R, d and r defining sides of a right triangle with an angle of ninety degrees between the sides corresponding to the distances d and r, an angle α between the sides corresponding to the distances d and R, an angle θ between the sides corresponding to the distances r and R, wherein the plurality of points are

Application No. 10/604,559
Docket No. 129180
Amendment dated April 27, 2005
Reply to Office Action of January 27, 2005

located by the equation:

$$\cos^2\theta + \cos^2\alpha = 1.$$

Claim 10 (currently amended): The method according to claim 1, wherein all of the points are located within an intermediate portion of the article between the central opening and the first secondary opening. ~~further comprising the step of calibrating the amplitude of the reflected ultrasonic signal returned from at least one of the points to a flat bottom hole standard reflector by causing the transducer to emit a calibration ultrasonic signal toward the central opening and obtaining a reflected calibration ultrasonic signal from the central opening, and calculating a relationship between the amplitude of the reflected ultrasonic signal returned from the one point to the flat bottom hole standard reflector according to the equation:~~

$$\cancel{A_f = \lambda d^2 P_f (b / R)^{1/2} / (2 (R - b) P_r)}$$

~~where A_f is the area of the flat bottom hole standard reflector, λ is the wavelength of sound in the article, d is the distance between the transducer and the at least one of the points, P_f is the amplitude of the reflected ultrasonic signal from the at least one of the points, b is the radius of the central opening, R is the distance between a center of the first secondary opening and a center of the central opening along one of the radials of the article, and P_r is the~~

~~amplitude of the reflected calibration ultrasonic signal from the central opening.~~

Claim 11 (original): The method according to claim 1, wherein the article is a machined gas turbine wheel, the central opening is an inner hub bore of the wheel, and the secondary openings are bolt holes of the wheel.

Claim 12 (currently amended): A method of ultrasonically inspecting a turbine wheel having a central hub bore, ~~bore and~~ a plurality of bolt holes radially spaced outward from the central hub bore and circumferentially spaced from each other along a circle concentric with the central hub, and an annular-shaped web region between the central hub bore and the bolt holes, the wheel being formed such that the web region potentially contains axial-radial oriented defects, ~~having the central hub bore as its center,~~ the method comprising the steps of:

mounting a plurality of ultrasonic transducers to form at least one transducer unit;

placing the transducer unit in a first of the bolt holes of the turbine wheel;

performing a pulse-echo diagnostic technique on the turbine wheel by causing the ultrasonic transducers to emit ultrasonic signals that intersect

radials of the turbine wheel at angles of approximately ninety degrees to the radials, the ultrasonic signals intersecting the radials at points located within the web portion of the wheel between the central hub bore and the first bolt hole so that each of a plurality of the points is located on a corresponding one of the radials, all of the plurality of points being located within the web portion; ~~a volume between the central hub bore and the circle on which the bolt holes are located;~~ and

placing the transducer unit in a sufficient additional number of the bolt holes and performing the pulse-echo diagnostic technique on the wheel to locate additional points throughout the web portion;

wherein at least one of ~~receiving reflected ultrasonic signals with~~ the ultrasonic transducers receives at least one reflected ultrasonic signal ~~that are~~ returned from at least one of the plurality of points at which an axial-radial oriented defect is present and oriented substantially perpendicular to the ultrasonic signal that returned the reflected ultrasonic signal.

Claim 13 (currently amended): The method according to claim 12, wherein the ultrasonic transducers are pulsed simultaneously during the performing steps. ~~step.~~

Claim 14 (currently amended): The method according to claim 12, wherein the ultrasonic transducers are pulsed at different times during the performing steps. ~~step.~~

Claim 15 (currently amended): The method according to claim 12, wherein the plurality of ultrasonic transducers is a phased array and the ultrasonic transducers are operated to focus the ultrasonic signals at predetermined depths from the bolt holes. ~~first bolt hole.~~

Claim 16 (original): The method according to claim 12, wherein the transducer unit comprises the plurality of ultrasonic transducers and a body on which the plurality of ultrasonic transducers are mounted, the body having a semicircular cross-section with a radius of curvature approximately equal to a radius of curvature of the bolt holes.

Claim 17 (original): The method according to claim 16, wherein the turbine wheel and the body on which the plurality of ultrasonic transducers are mounted are formed of the same material.

Claim 18 (original): The method according to claim 12, wherein each

of the bolt holes has a center located a constant distance R from a center of the central hub bore along one of the radials of the turbine wheel, and each of the plurality of points is located a distance d from the center of the bolt hole and a distance r from the center of the central hub bore, the distances R, d and r defining sides of a right triangle with an angle of ninety degrees between the sides corresponding to the distances d and r, an angle α between the sides corresponding to the distances d and R, an angle θ between the sides corresponding to the distances r and R, wherein the plurality of points are located within the turbine wheel by the equation:

$$\cos^2\theta + \cos^2\alpha = 1.$$

Claim 19 (original): The method according to claim 12, further comprising the step of calibrating the amplitude of the reflected ultrasonic signals returned from the plurality of points to a flat bottom hole standard reflector by causing the transducer to emit a calibration ultrasonic signal toward the central hub bore and obtaining a reflected calibration ultrasonic signal from the central hub bore, and then calculating a relationship between the amplitude of the reflected ultrasonic signals returned from the plurality of points to the flat bottom hole standard reflector according to the equation:

$$A_f = \lambda\, d^2\, P_f\, (b / R)^{1/2} / (2\, (R - b)\, P_r)$$

where A_f is the area of the flat bottom hole standard reflector, λ is the wavelength of sound in the wheel, d is the distance between the transducer and the at least one of the points, P_f is the amplitude of the reflected ultrasonic signal from the at least one of the points, b is the radius of the central hub bore, R is the distance between a center of the first bolt hole and a center of the central hub bore along one of the radials of the wheel, and P_r is the amplitude of the reflected calibration ultrasonic signal from the central hub bore.

Claim 20 (original): The method according to claim 12, wherein the step of performing the pulse-echo diagnostic technique on the turbine wheel is repeated for each of the bolt holes using the at least one transducer unit or another of the at least one transducer.

Claim 21 (currently amended): An ultrasonic inspection system for a disk-shaped article having a central opening and a plurality of secondary openings radially spaced outward from the central opening and circumferentially spaced from each other, the ultrasonic inspection system comprising:

at least one ultrasonic transducer placed in at least a first of the secondary openings of the article <u>and calibrated on the basis of the amplitude</u>

<u>of ultrasonic signals reflected from the central opening</u>, the ultrasonic transducer being configured and oriented to perform a pulse-echo diagnostic technique on the article by emitting ultrasonic signals that intersect radials of the article at angles of approximately ninety degrees to the radials, the ultrasonic signals intersecting the radials at points so that a plurality of the points are located on a plurality of the radials.

Claim 22 (original): The ultrasonic inspection system according to claim 21, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers placed in the first secondary opening, the system further comprising means for simultaneously pulsing the ultrasonic transducers.

Claim 23 (original): The ultrasonic inspection system according to claim 21, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers placed in the first secondary opening, the system further comprising means for pulsing the ultrasonic transducers at different times.

Claim 24 (original): The ultrasonic inspection system according to claim 21, wherein the at least one ultrasonic transducer is one of a phased array of ultrasonic transducers placed in the first secondary opening, the

system further comprising means for operating the ultrasonic transducers to focus the ultrasonic signals at predetermined depths from the first secondary opening.

Claim 25 (original): The ultrasonic inspection system according to claim 21, wherein the central opening is a through-hole having an axis of symmetry and each of the secondary openings is a through-hole having an axis of symmetry that is substantially parallel to the axis of the central opening.

Claim 26 (currently amended): The ultrasonic inspection system according to claim 21, wherein all of the plurality of points are located between the central opening and a circle <u>concentric with</u> ~~having~~ the central opening ~~as its center~~ and on which the first secondary opening is located.

Claim 27 (original): The ultrasonic inspection system according to claim 21, wherein the at least one ultrasonic transducer is one of an array of ultrasonic transducers mounted on a body to form a transducer unit that is placed in the first secondary opening, the body having a semicircular cross-section with a radius of curvature approximately equal to a radius of curvature of the first secondary opening.

Claim 28 (original): The ultrasonic inspection system according to claim 27, wherein the article and the body on which the transducer unit is mounted are formed of the same material.

Claim 29 (original): The ultrasonic inspection system according to claim 21, wherein the first secondary opening has a center located a constant distance R from a center of the central opening along one of the radials of the article, and each of the points is located a distance d from the center of the secondary opening and a distance r from the center of the central opening, the distances R, d and r defining sides of a right triangle with an angle of ninety degrees between the sides corresponding to the distances d and r, an angle α between the sides corresponding to the distances d and R, an angle θ between the sides corresponding to the distances r and R, the locations of the plurality of points within the article being determined by the equation:

$$\cos^2\theta + \cos^2\alpha = 1.$$

Claim 30 (original): The ultrasonic inspection system according to claim 21, wherein the article is a machined gas turbine wheel, the central opening is an inner hub bore of the wheel, and the secondary openings are bolt holes of the wheel.

Claim 31 (currently amended): A ultrasonic inspection system for a turbine wheel having a central hub bore and a plurality of bolt holes radially spaced outward from the central hub bore and circumferentially spaced from each other along a circle concentric with ~~having~~ the central hub bore ~~as its center~~, the ultrasonic inspection system comprising:

a plurality of ultrasonic transducers mounted to form at least one transducer unit and calibrated on the basis of the amplitude of ultrasonic signals reflected from the central hub bore, the transducer unit being located in a first of the bolt holes of the turbine wheel, the ultrasonic transducers being configured and oriented within the first bolt hole to perform a pulse-echo diagnostic technique on the turbine wheel by emitting ultrasonic signals that intersect radials of the turbine wheel at angles of approximately ninety degrees to the radials, the ultrasonic signals intersecting the radials at points so that each of a plurality of the points is located on a corresponding one of the radials, all of the plurality of points being located within a volume between the central hub bore and the circle on which the bolt holes are located.

Claim 32 (original): The ultrasonic inspection system according to claim 31, further comprising means for simultaneously pulsing the ultrasonic transducers.

Claim 33 (original): The ultrasonic inspection system according to claim 31, further comprising means for pulsing the ultrasonic transducers at different times.

Claim 34 (original): The ultrasonic inspection system according to claim 31, wherein the plurality of ultrasonic transducer is a phased array, the system further comprising means for operating the ultrasonic transducers to focus the ultrasonic signals at predetermined depths from the first bolt hole.

Claim 35 (original): The ultrasonic inspection system according to claim 31, wherein the transducer unit comprises the plurality of ultrasonic transducers and a body on which the plurality of ultrasonic transducers are mounted, the body having a semicircular cross-section with a radius of curvature approximately equal to a radius of curvature of the bolt holes.

Claim 36 (original): The ultrasonic inspection system according to claim 35, wherein the turbine wheel and the body on which the plurality of ultrasonic transducers are mounted are formed of the same material.

Claim 37 (original): The ultrasonic inspection system according to

claim 31, wherein each of the bolt holes has a center located a constant distance R from a center of the central hub bore along one of the radials of the turbine wheel, and each of the plurality of points is located a distance d from the center of the bolt hole and a distance r from the center of the central hub bore, the distances R, d and r defining sides of a right triangle with an angle of ninety degrees between the sides corresponding to the distances d and r, an angle α between the sides corresponding to the distances d and R, an angle θ between the sides corresponding to the distances r and R, wherein the plurality of points are located within the turbine wheel by the equation:

$$\cos^2\theta + \cos^2\alpha = 1.$$